

Physics education research: Resources for graduate student instructors

Zosia A. C. Krusberg*

*Department of Physics, University of Chicago
5640 S. Ellis Avenue, Chicago, IL 60637, USA*

What a blessing it would be, Agathon, if wisdom could run from the fuller amongst us to the emptier, while we touch one another, as when two cups are placed side by side a bit of wool conveys water from the fuller to the emptier.

Socrates, *Plato's Symposium*

Abstract

This resource letter intends to provide physics instructors — particularly graduate student teaching assistants — at the introductory university level with a small but representative collection of resources to acquire a familiarity with research in physics education for guidance in everyday instruction. The resources are in the form of books, articles, websites, journals, and organizations.

*Electronic address: zosia@uchicago.edu

1 Books

This section presents summaries of a number of books on research in physics education, research-based instructional techniques, and general science education that are of particular practical value to physics instructors at the beginning of their teaching careers. Additional publications are listed in the references section.

1.1 Physics Education

Since the emergence of the field of physics education research (PER) several decades ago, a large collection of books on physics education have been published. These books are of tremendous value to physics instructors as they summarize research findings on how students at all educational levels learn physics, which can have significant impact on everything from lecturing style to choice of classroom activities.

- E. Redish, *Teaching Physics with the Physics Suite* (John Wiley & Sons, Hoboken, 2003)

Intended as an instructor's resource guide to accompany *The Physics Suite*, an introductory physics curriculum, this succinct and highly readable book is an incredible resource to physics instructors — both teaching assistants and professors — at the university level. Redish provides an overview of research in cognitive science as it relates to physics instruction, a discussion of the goals of physics instruction, an analysis of common student evaluation methods and surveys of our teaching, and an extensive review of curricula and instructional methods informed by research in cognitive science and physics education. As a bonus, the accompanying CD contains a vast number of resources including pre- and posttests to evaluate student learning, relevant articles from the American Journal of Physics, syllabi of courses in physics education, and much more. In sum, this is an excellent introduction to the field of physics education as well as a practical guide for instructors.

- A. Arons, *Teaching Introductory Physics* (John Wiley & Sons, Hoboken, 2001)

This massive work by one of the pioneers in the field of physics education is invaluable to instructors wishing to use results from physics education research to inform their teaching. The book contains updated versions of two of Arons' previous publications: *A Guide to Introductory Physics Teaching* and *Homework and Test Questions for Introductory Physics Teaching*. Furthermore, the author includes a third section, entitled *Introduction to the Classical Conservation Laws*. In the first section, Arons offers a detailed analysis of the preconceptions that students bring into the introductory physics classroom, organized by topic (e.g., Rectilinear Kinematics, Static Electricity, Early Modern Physics), all along advising the reader on how to best guide students through these topics. The second section is similarly organized, presenting an extensive collection of potential homework and exam problems. The third section explains a novel approach to the teaching of the concepts of momentum and energy.

- R. Knight, *Five Easy Lessons: Strategies for Successful Physics Teaching* (Addison Wesley, Boston, 2002)

Knight's book, composed as a practical manual for physics instructors, consists of two parts: first, a rather brief overview of results from physics education research and reasons for changing traditional (lecture-based) instruction, and second, a guide to common student preconceptions in introductory physics topics along with sample reading quiz and exam questions. Though not as extensive as Redish in the former, or Arons in the latter, for instructors with time constraints, it is a highly effective book.

1.2 Research-Based Instructional Techniques

As the field of physics education research has grown, a large collection of educational techniques, tools, and curricula have been developed based on its findings. Many of these techniques are easily implemented in the classroom setting and require little additional preparation. The following publications present some of these techniques from the context of PER. For further examples, see Chapters 6–9 in Redish's *Teaching Physics*, described above.

- W. Christian and M. Belloni, *Physlet Physics* (Prentice Hall, Upper Saddle River, 2003)

Physlets are small Java-generated computer animations that provide visualizations of various physical phenomena generally explored in first-year university physics courses. The Physlet exercises — categorized into Illustrations, Explorations, and Problems, each with different pedagogical goals — provide students with opportunities to confront their preconceptions about these physical phenomena and to explore these in ways not possible with static textbook images. Projected in a classroom, they can offer the instructor with a useful means to introduce and explain new concepts and guide student discussion.

- P. Heller and K. Heller, *Collaborative Group Problem Solving* (University of Minnesota, 1999)

<http://groups.physics.umn.edu/physed/Research/CGPS/GreenBook.html>

Though extensive research has investigated how students learn to problem solve in physics and mathematics, few instructional techniques designed to develop students' problem-solving skills have been created. The University of Minnesota's Collaborative Group Problem Solving curriculum is an impressive exception. This online publication describes the research behind the curriculum as well as the activities it entails. Though implementing the full curriculum is an extensive effort, physics instructors can use this publication to gain valuable insight into how to aid students in developing effective problem solving techniques in introductory physics courses.

- E. Mazur, *Peer Instruction: A User's Manual* (Prentice Hall, Upper Saddle River, 1996)

Peer Instruction is an interactive physics curriculum based on extensive research in physics education. With the use of ConcepTests, short conceptual questions checking student understanding of individual physics concepts, in so-called think-pair-share activities, student preconceptions are elicited and confronted. This book contains a vast collection of these ConcepTests, organized by topic; these can also be found online at Project Galileo (<http://galileo.harvard.edu/>).

- T. O'Kuma, D. Maloney, and C. Hieggelke, *Ranking Task Exercises in Physics* (Prentice Hall, Upper Saddle River, 2003)

Though neither an instructional method nor a curriculum, this book contains a large collection of so-called Ranking Task Exercises that call upon students to answer questions on introductory physics topics in a qualitative way. These exercises present a general physical scenario (such as a gas-filled cylinder) followed by six specific cases differing in the value of some physical variables (such as temperature and volume). Students then have to rank these specific cases based on the value of some other variable (such as gauge pressure). By preventing “plugging and chugging,” the questions force students to think about the qualitative relationships between variables inherent in physical laws, thereby helping them develop an intuition about physics concepts. The book contains problems on most topics covered in first-year physics courses.

1.3 General Science Education

Educational research is a rapidly expanding field, with new findings emerging in such varied areas as neuroscience, cognitive science, and educational technologies. For those with an interest in current developments in educational research, a number of books discussing these research findings are presented here. The National Science Teachers Association (NSTA) publishes many of these books, available in their online store (<http://www.nsta.org/store/>).

- P. E. Blosser, *How to... Ask the Right Questions* (NSTA Press, Arlington, 1991)

Asking questions is a fundamental and essential part of science instruction; this booklet offers guidance in how to analyze and improve questioning techniques.

- M. Druger, E. D. Siebert, and L. W. Crow, eds., *Teaching Tips: Innovations in Undergraduate Science Instruction* (NSTA Press, Arlington, 2004)

Originally published for the 25th anniversary of the Society for College Science Teachers, this publication presents over fifty innovative instructional methods for college science courses organized into pedagogical practices, assessment activities, and content challenges.

- J. J. Mintzes and W. H. Leonard, eds., *Handbook of College Science Teaching* (NSTA Press, Arlington, 2006)

Intended as an authoritative guide to contemporary college science teaching, this book is an invaluable guide to instructors: it presents current theories and research findings in science education, and offers models of teaching and learning that extend beyond traditional lecturing.

- National Research Council, *How People Learn: Brain, Mind, Experience, and School* (National Academies Press, Washington D. C., 2000)

<http://www.nap.edu/books/0309070368/html/>

This book, the result of work by two committees of the Commission on Behavioral and Social Sciences and Education of the National Research Council, describes our current understanding of mind, brain, and the process of learning, and summarizes effective curricula based on these research areas in areas ranging from history to physics.

- D. Rose and A. Meyer, *Teaching Every Student in the Digital Age: Universal Design for Learning* (Association for Supervision & Curriculum Development, Alexandria, 2002)

<http://www.cast.org/teachingeverystudent/ideas/tes/>

Initially intended as a curriculum for students with special learning needs, Universal Design for Learning (UDL) has transformed the way educators think about learning for all students. The first part of this book presents the case for UDL by describing neuroscientific evidence for learner differences and how insights about special-needs students can inform more effective curricula. The second part describes the practical applications of UDL in the classroom, particularly in the form of educational technologies.

2 Articles

Journal articles in physics education are now published regularly by several journals (see below). However, a number of recent articles are particularly useful to physics instructors looking for practical guidance in their teaching and are therefore listed here. Many of these are taken from the “For the New Teacher” column in *The Physics Teacher*.

- P. Blanton, “Constructing knowledge,” *The Physics Teacher* 41, 125 (2003)
- P. Blanton, “Learning to listen to what your students say,” *The Physics Teacher* 43, 124 (2005)
- K. A. Harper, “Student problem-solving behavior,” *The Physics Teacher* 44, 250 (2006)
- R. Knight, “Know your students,” *The Physics Teacher* 42, 380 (2004)

- G. Marbach-Ad and P. G. Sokolove, “Good science begins with good questions,” *Journal of College Science Teaching* 30, 192
- L. McCullough, “Gender in the classroom,” *The Physics Teacher* 45, 316 (2007)
- E. F. Redish, “Implications of cognitive studies for teaching physics,” *American Journal of Physics* 62, 796 (1994)
- F. Reif, “Millikan Lecture 1994: Understanding and teaching important scientific thought processes,” *American Journal of Physics* 63(1), 17 (1995)
- B. Royce, “Question their answers,” *The Physics Teacher* 42, 444 (2004)
- T. F. Slater, “The first three minutes...of class,” *The Physics Teacher* 44, 477 (2006)

3 Journals

A number of journals have been created in recent years to highlight research carried out in physics education. These are published regularly and can provide your teaching with new ideas and useful guidance.

- American Journal of Physics
<http://scitation.aip.org/ajp/>
- Physical Review Special Topics: Physics Education Research
<http://prst-per.aps.org/>
- The Physics Teacher
<http://scitation.aip.org/tpt/>

Additionally, the National Science Teachers Association (NSTA) publishes a monthly journal aimed at presenting effective teaching strategies in undergraduate science instruction:

- Journal of College Science Teaching

4 Organizations

Two organizations provide useful resources for physics instructors:

- American Association of Physics Teachers (AAPT)

<http://www.aapt.org/>

The AAPT — which is in the process of changing its name to the Association for the Advancement of Physics Teaching to better represent its mission — places a large emphasis on professional development in the form of workshops and conferences, which makes its website less useful for specific teaching advice. However, it's worth checking out once in a while if only for its monthly AAPT News (<http://www.aapt.org/aboutaapt/news.cfm>). More importantly, the AAPT maintains comPADRE: Resources for Physics and Astronomy Education, which contains a vast number of resources for physics instructors (<http://www.compadre.org/>).

- National Science Teachers Association (NSTA)

<http://www.nsta.org/>

The NSTA website provides ample resources for science instructors. The main page contains a frequently-updated collection of recent news in science education, and the College Science Classroom page (<http://www.nsta.org/college/>) provides links to articles in the current issue of the Journal of College Science Teaching. The most impressive gem of the NSTA website, however, is the newly released NSTA Learning Center (<http://learningcenter.nsta.org/>), which contains a large collection of well-organized resources on everything from theories of learning to concept-specific activities. You may want to consider becoming a member, which provides you with full access to the online resources as well as a subscription to an NSTA journal publication of your choice.

References

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- [18] B. Yeany, *If You Build It, They Will Learn: 17 Devices for Demonstrating Physical Science* (NSTA Press, Arlington, 2006)